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GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT INITIATION

Date: June 25, 1975

Project Title: Instructional Scientific Equipment

Project No: E-19-551

Principal Investigator Dr. Robert F. Hochman

Sponsor: National Science Foundation

Agreement Period: From June 1, 1975 Until May 31, 1977

Type Agreement: Grant No. HES75-11226

Amount:
15,000 NSF
15,000 GIT (E-19-215)
30,000 TOTAL

Reports Required: Final Technical Report

Sponsor Contact Person (s):

Instructional Scientific Equipment Program
National Science Foundation
Washington, D. C. 20550

Assigned to: Chemical Engineering

COPIES TO:

Principal Investigator	Library
School Director	Rich Electronic Computer Center
Dean of the College	Photographic Laboratory
Director, Research Administration	Project File
Director, Financial Affairs (2)	
Security-Reports-Property Office	
Patent Coordinator	Other

RA-3 (6-71)

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GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 2/13/78

Project Title: Instructional Scientific Equipment

Project No: E-19-551

Project Director: R. F. Hochman

Sponsor: National Science Foundation

Effective Termination Date: 5/31/77

Clearance of Accounting Charges: 5/31/77

Grant/Contract Closeout Actions Remaining:

- _ Final Invoice and Closing Documents
- x Final Fiscal Report
- _ Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other ______

Assigned to: Chemical Engineering (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
✓Security Coordinator (OCA)
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Library, Technical Reports Section
Office of Computing Services
Director, Physical Plant
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other ______

CA-4 (3/76)

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

FINAL PROJECT REPORT
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I–PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
Georgia Institute of Technology 210 North Avenue N.W. Atlanta, GA 30332	Inst. Sc. Equipment	HES75-11226
	4. Award Period From 6/1/75 To 9/30/77	5. Cumulative Award Amount $15,000

6. Project Title

Instructional Scientific Equipment Program in Corrosion

PART II–SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

An original report was submitted to the Director of the Instructional Scientific Equipment Program of NSF on January 31, 1978. A copy of this report is attached and summarized below.

The improvement plan provided in the proposal has been full implemented. A complete set of undergraduate laboratory corrosion experiments have been prepared for the course, Metallurgy 4491. The course hours have also been changed to reflect the one hour laboratory for the course. The equipment purchased was vital to the development of this laboratory for the course. Experiments to measure electrode corrosion potentials, galvanic corrosion, concentration cell corrosion, polarization curves, corrosion rate measurements, and direct oxidation were implemented. In addition, highly localized corrosion experiments involving pitting, crevice corrosion and stress corrosion cracking were developed. An additional experiment on corrosion inhibitors was also added. These nine laboratory experiments are briefly outlined in the attached letter report.

Because of the importance and timeliness of corrosion awareness related to the structural integrity in engineering design as well as the conservation of our material and energy resources, a portion of the program was to establish undergraduate laboratories in the introductory metallurgy service course as well as providing laboratories in material courses for other disciplines. A series of two week laboratories, in the introductory metallurgy course, taught for metallurgy, chemical engineering, and elective students from other disciplines was developed.

In addition special one period labs have been experimentally evaluated in mechanical engineering and civil engineering in their normal material courses.

PART III–TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (√)	Approx. Date
a. Abstracts of Theses					
b. Publication Citations					
c. Data on Scientific Collaborators					
d. Information on Inventions					
e. Technical Description of Project and Results					
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date

E-19-551

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
CHEMICAL ENGINEERING

January 31, 1978

Director
Instructional Scientific Equipment Program
Division of Higher Education in Science
National Science Foundation
Washington, DC 20550

RE: Final Report on the Instructional Scientific Equipment Program Grant #HES75-~~1126~~ 11226

Dear Sir:

The improvement plan provided in the proposal has been fully implemented. A complete set of undergraduate laboratory corrosion experiments have been prepared for the course, Metallurgy 4491. The course hours have also been changed to reflect the one hour laboratory for the course. The equipment purchased was vital to the development of this laboratory for the course. Experiments to measure electrode corrosion potentials, galvanic corrosion, concentration cell corrosion, polarization curves, corrosion rate measurements, and direct oxidation were implemented. In addition, highly localized corrosion experiments involving pitting, crevice corrosion and stress corrosion cracking were developed. An additional experiment on corrosion inhibitors was also added. These nine laboratory experiments are briefly outlined in the attached Enclosure 1 of this letter.

Because of the importance and timeliness of corrosion awareness related to the structural integrity in engineering design as well as the conservation of our material and energy resources, a portion of the program was to establish undergraduate laboratories in the introductory metallurgy service course as well as providing laboratories in material courses for other disciplines. A series of two week laboratories, in the introductory metallurgy course, taught for metallurgy, chemical engineering, and elective students from other disciplines was developed. The outline of this laboratory is attached as Enclosure 2.

In addition special one period labs have been experimentally evaluated in mechanical engineering and civil engineering in their normal material courses.

The attached enclosures also provide a list of the equipment used in these experiments which was made possible through purchases on this program. The results have been extremely gratifying and the interest, in general, in corrosion and conservation of materials, particularly by junior and senior chemical,metallurgical and mechanical engineers has been most gratifying.

SKB

The awareness, because of the laboratories resulting in student discussions, has had a general student impact on engineering design courses since several groups have requested corrosion evaluation of design projects.

A problem in carrying out such a project is the faculty time necessary to perform all the necessary work involved in developing and adding experiments, utilizing and implementing laboratory procedures, as well as operational shakedown of all new equipment. This may not be a function in many laboratory grants, since there may be less experiment development, however, the entire laboratory course of nine separate experiments plus five to six additional experiments for labs in other diciplines has taken extensive faculty time. I have been fortunate in having the time provided by institutional special support, however, in some cases, projects involving development in curriculum might need some assigned faculty personal service funds on the matching program. I recommend this only in situations where faculty to implement the grant is large and NSF-Institutional matching funds for the project director would allocate the time necessary to implement the laboratory development. Small personal services funds should be on a no overhead basis and be provided only when sufficient justification can be made for faculty time.

This particular grant, because of the uniqueness of most of the equipment, could not make use of any Federal excess property that we were aware of. In general, the program can be considered as being fully implemented and with excellent results.

Respectfully submitted,

R. F. Hochman
Project Director
Associate Director for Metallurgy

Enclosure 1 : MET 4491 Laboratory Experiments
Enclosure 2: MET 3301 Laboratory Experiments
Enclosure 3: Section B. Table of Equipment Substitutions and Additions

Enclosure 1

MET 4491

CORROSION AND PROTECTIVE MEASURES
LABORATORY EXPERIMENTS

Lab #1. Basic Corrosion Measurements

Objective: To acquaint the students with techniques of measurement of electrode potentials, currents, pH, specific ion concentration, etc.

Brief Outline: Students are instructed in the use of electrometers, zero- impedance ammeters, pH and specific ion meters. Reference, redox, pH, and specific ion electrodes are shown and explained. Students make simple measurements of corrosion potentials, redox potentials, pH of the electrolyte, concentration of chlorides, etc.
A set of electrodes is prepared and a corrosion potential vs. time measurement is initiated, to be left unattended until the next lab period when the data are processed and evaluated.

Equipment: Electometer, Current Meter, pH Meter, Data Acquisition System.

Lab #2. Galvanic Corrosion Cell

Objective: To demonstrate galvanic corrosion and basic parameters and relationships in a galvanic corrosion cell.

Brief Outline: Students measure open circuit corrosion potentials of two dissimilar electrodes in the same electrolyte. The electrodes are then connected through a variable resistor, and the electrode potentials and the galvanic current are measured at various settings of the resistor. Data are processed and plotted as polarization curves of both electrodes. An automatic recording setup is then used to obtain similar data for other combinations of metals, and for different anode/cathode ratios.

Equipment: Electrometers, current meter, X-Y-Y' recorder.

Lab #3. Concentration Cells

Objective: To demonstrate various concentration cells, such as metal ion concentration cell, oxygen concentration cell (differential aeration), etc.

Brief Outline: Students first measure electrode potentials of two identical electrodes in electrolytes with different concentrations of ions of the same metal. The data are compared with potentials calculated from Nernst equation.

A differential aeration cell is set (double cell with porous membrane separating the compartments), and the open circuit potential difference is measured. The experiment starts with aerated electrolyte in both compartments; the solution in one compartment is then deaerated. The potential difference is measured. After completion of the measurement the cell is reversed. Current flowing between the electrodes when the circuit is closed is measured.

Equipment: Electrometer, Current meter, Data Acquisition System, X-Y-Y' recorder.

Lab #4. Polarization Curves

Objective: To teach the students the use of an electronic potentiostate. To demonstrate cathodic and anodic polarization curves of active and passivating materials and show important parameters.

Brief Outline: The function and operation of an electronic potentiostat and accessories are explained. Students prepare a three-electrode cell and manually record cathodic and anodic polarization characteristics of an active metal. An automatic measurements is performed on a passivating electrode. The effect of dissolved oxygen is demontrated by making the measurements both in deaerated and aerated electrolytes.

Equipment: Electronic potentiostat, Programmer, X-Y recorder.

Lab #5. Corrosion Rate Measurements

Objective: To show various techniques of corrosion rate determination: weight loss measurements, Tafel extrapolation, polarization resistance measurements (2- and 3-electrode techniques). To show the effect of variables, such as oxygen concentration, on the corrosion rate of steel.

Brief Outline: A set of electrodes is prepared for wright loss measurements. The experiment is initiated, to be concluded in the next lab period. Electrode potential data are automatically recorded.

Polarization resistance measurement is explained. Students use commercial 2-electrode and 3-electrode corrosion meters to determine corrosion rate of several materials.

Corrosion rate of steel in tap water as a function of dissolved oxygen concentration is determined; the polarization resistance technique is used to measure the corrosion rate, and the electrolyte is deaerated in steps and the oxygen concentration is measured. Data are plotted as corrosion rate vs. oxygen concentration.

Equipment: Data acquisition system, Corrosion Meters, Dissolved Oxygen Analyzer.

Lab #6. Dry Oxidation

Objective: To demonstrate various oxidation laws and oxidation characteristics of various materials.

Brief Outline: Students prepare samples of various metals, weigh them and oxidize them in an oven. The weight change is determined periodically and data are plotted as weight change vs. time. The surface changes are examined using an optical stereo microscope and metallograph.

Equipment: Oven, balance, stereo microscope and accessories.

Lab #7. Pitting and Crevice Corrosion

Objective: To demonstrate the pitting and crevice corrosion phenomena; to explore the electrochemical conditions and examine the corrosion effects.

Brief Outline: Pitting is initiated potentiostatically in a special cell allowing observation of the specimen surface through a stero microscope. Potential is varied and the progress of pitting is observed. An artifical crevice cell which allows measurement of potentials and current and determination of the solution chemistry in the crevice is used. The cell is assembled and measurement is initiated in the lab period, to be left unattended until the next period, data being automatically recorded.

Equipment: Potentiostat, Data Acquisition System, Electrometer, Current Meter, pH Meter, Stereo Microscope.

Lab #8. Stress Corrosion Cracking

Objective: To demonstrate the stress corrosion cracking phenomenon; to show the effect of the conditions and to examine the apperance of fracture surfaces.

Brief Outline: Notched specimens of a rapidly cracking material (such as Type 4340 high strength steel) are loaded in a corrosive environment. Students observe crack propagation and estimate the rate. The specimen is then broken and the fracture surface are examined and photographed in an optical stereo microscope.

Equipment: Stereo microscope and accessories.

Lab #9. Corrosion Inhibitors

Objective: To demonstrate and evaluate the effectiveness of various corrosion inhibitors.

Brief Outline: Various metals are prepared as electrodes and exposed to solutions with and without inhibitors. Oxidizing inhibitors are used in several concentrations to demonstrate the importance of the effect. Corrosion potentials and corrosion rates are measured. Surfaces are examined before and after the exposure.

Equipment: Electrometers, Data Acquisition System, Corrosion Meters, Balance, Stereo Microscope and accessories.

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MET 3301

PRINCIPLES AND APPLICATIONS OF ENGINEERING MATERIALS
CORROSION LABORATORY

A. Basic Corrosion Measurements

Objective: To acquaint students with techniques of measurement of electrode potentials, galvanic currents, pH, etc.

Brief Outline: Students are instructed in the use of electrometers, zero-impedance ammeters, and pH meters. Reference, redox, and pH electrodes are shown and explained. Students make simple measurements of electrode potentials and pH electrolytes.

Equipment: Electrometer, Current Meter, pH Meter.

B. Galvanic Corrosion Cell

Objective: to demonstrate galvanic corrosion and basic relationships in a galvanic corrosion cell.

Brief Outline: Students measure open circuit corrosion potentials of two dissimiliar electrodes in the same electrolyte. The electrodes are then connected through a variable resistor, and the electrode potentials and the galvanic current are measured at various settings of the resistor. Data are plotted as polarization curves of both electrodes.

Equipment: Electrometers, Current Meter.

C. Concentration Cell

Objective: To demonstrate differential aeration as an example of a concentration cell.

Brief Outline: Students first measure the electrode potentials of two identical electrodes in the smae electrolyte in a two-compartment cell with a porous membrane separating the compartments. The electrolyte in one of the compartments is then deaerated and the electrode potential difference is monitored. When a steady potential difference is reached the cell is reversed.

Equipment: Electrometer.

Enclosure 3

INSTRUCTIONAL SCIENTIFIC EQUIPMENT PROGRAM
SUMMARY REPORT FORM

Proposal/Grant Number:
HES75-1126

Date: January 20, 1978

Discipline: Corrosion

TO: Division of Higher Education in Science
National Science Foundation

FROM: Dr. Robert F. Hochman
Project Director

Georgia Institute of Technology   Atlanta   Georgia

Equipment Substitution and Additions

Request Equipment as Listed in Original Proposal		Cost and Description of Actual Purchases	
Estimated Cost	Description	Actual Cost	Description
295 1,550	Galvanostat Potentiostat	1,898	Potentiostat/Galvanostat
3,800 3,000 1,470 495	Data Logger Data Coupler/Punch Tape Reader Electrometer	11,565	Data acquisition system including electrometer
935	Precision balance		
4,100	Fatigue Machine		
525	Z-scope		
650	Corrosometer		
		3,332	X-Y-Y' recorder
		429	Distillation still
		1,109	Accessories for Stero Microscope and Macrophotography (4x5 and 35 mm cameras, illuminator, exposure meter)